US008459869B2

(12) **United States Patent**
Enomoto

(10) **Patent No.: US 8,459,869 B2**
(45) **Date of Patent: Jun. 11, 2013**

(54) **RADIATION DETECTION DEVICE, IMAGING CONTROL DEVICE, RADIATION IMAGING SYSTEM, AND SELF DIAGNOSTIC METHOD OF RADIATION DETECTION DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 244 days.

(21) Appl. No.: **12/923,217**

(22) Filed: **Sep. 9, 2010**

(65) **Prior Publication Data**

US 2011/0075811 A1 Mar. 31, 2011

(30) **Foreign Application Priority Data**

Sep. 25, 2009 (JP) 2009-220290

(51) **Int. Cl.**
G01D 18/00 (2006.01)

(52) **U.S. Cl.**
USPC **378/207**; 378/117; 378/98.8

(58) **Field of Classification Search**
USPC 378/207, 98.8, 117
See application file for complete search history.

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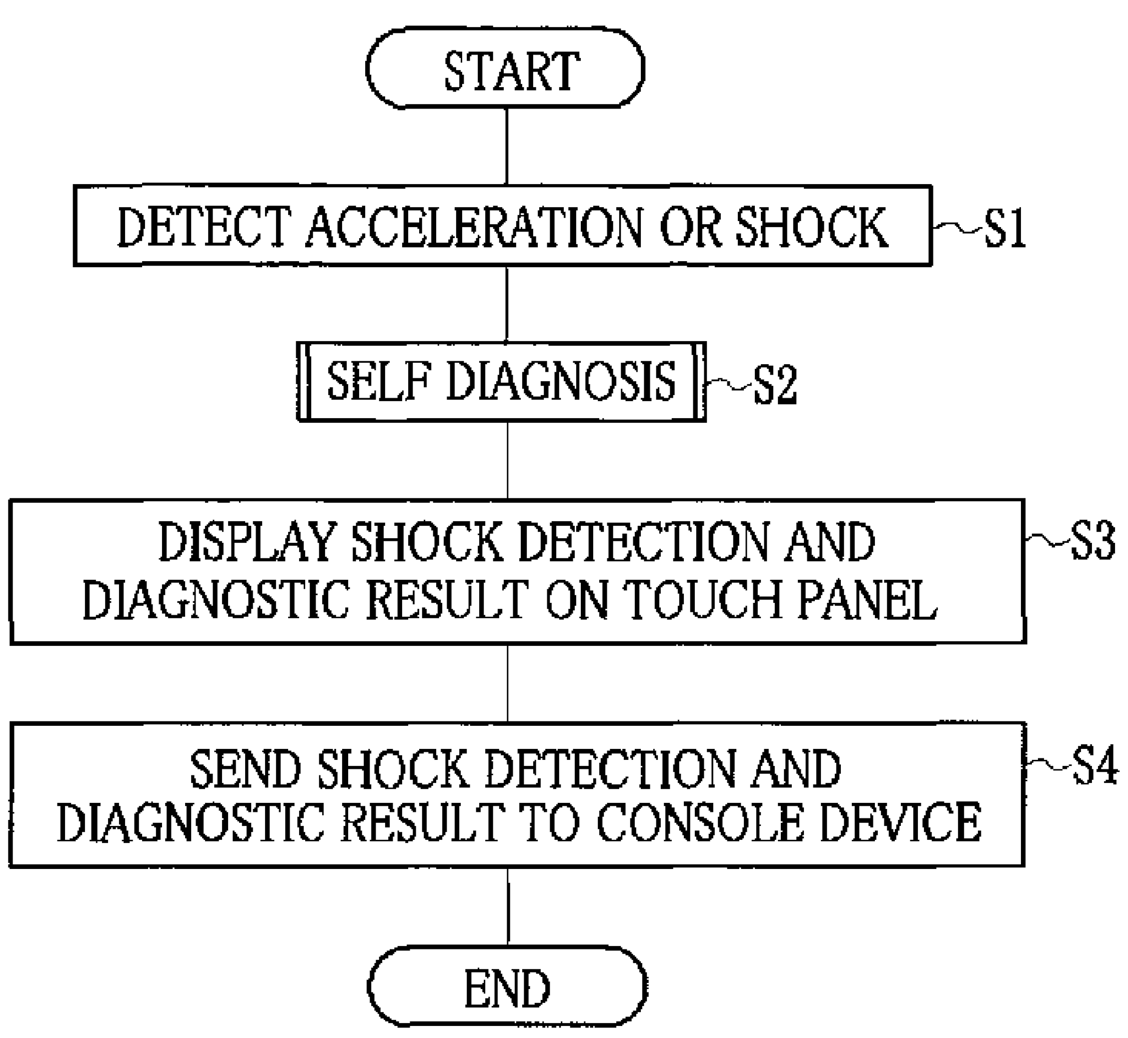
(57) **ABSTRACT**

In a cassette-type X-ray detection device, an X-ray detector and a self diagnostic circuit are contained in a cassette casing. When the cassette-type X-ray detection device gets a shock, the self diagnostic circuit is actuated. The self diagnostic circuit reads out from the X-ray detector an offset image being a dark current image, and analyzes the offset image. The self diagnostic circuit finds out an abnormal portion from the offset image, and diagnoses whether the X-ray detector is available, unavailable, or partly available based on the size and position of the abnormal portion. Shock detection and a diagnostic result are displayed on a touch panel provided in the cassette casing, and sent to a console device via a communication unit.

11 Claims, 13 Drawing Sheets



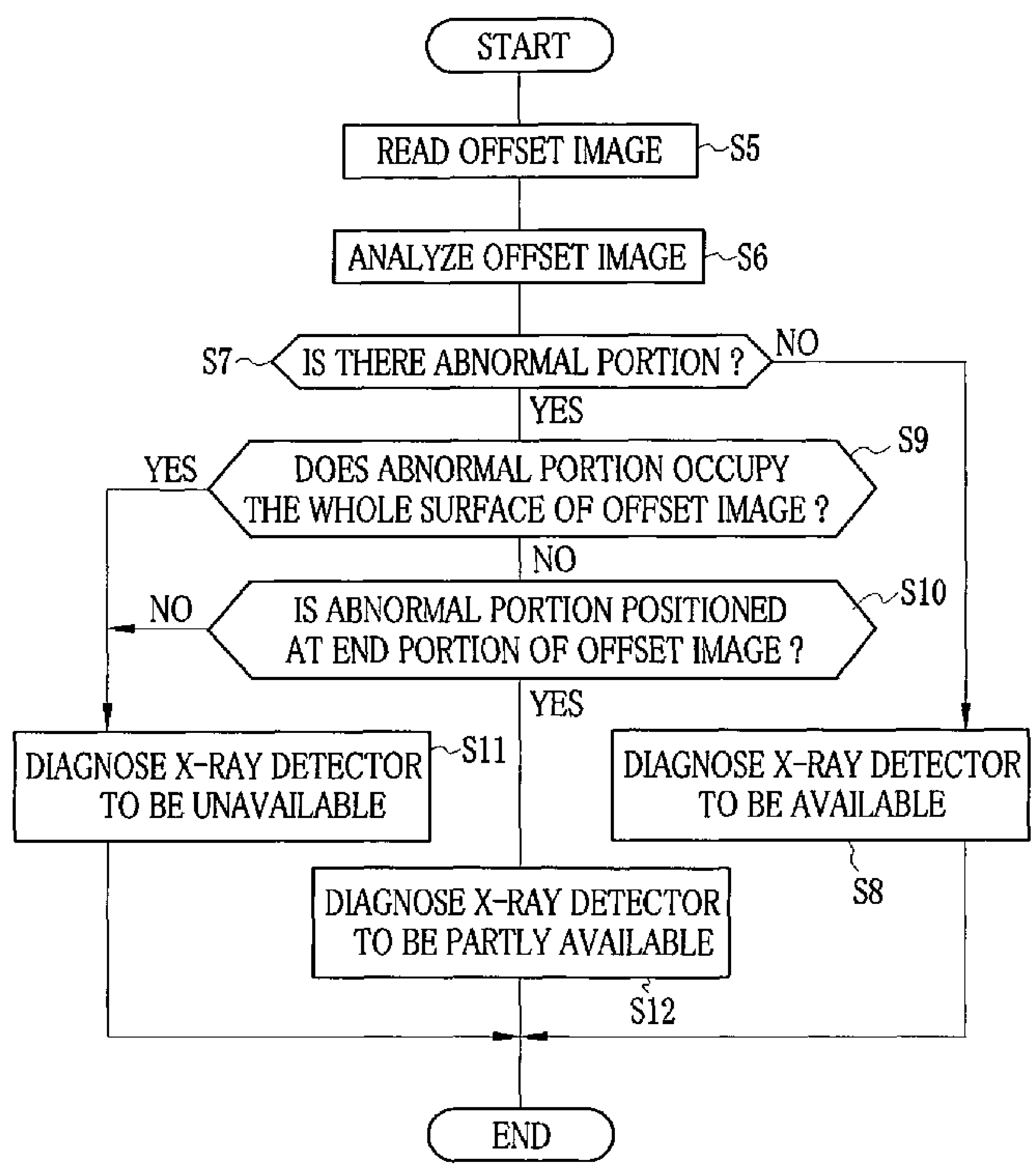


FIG. 1

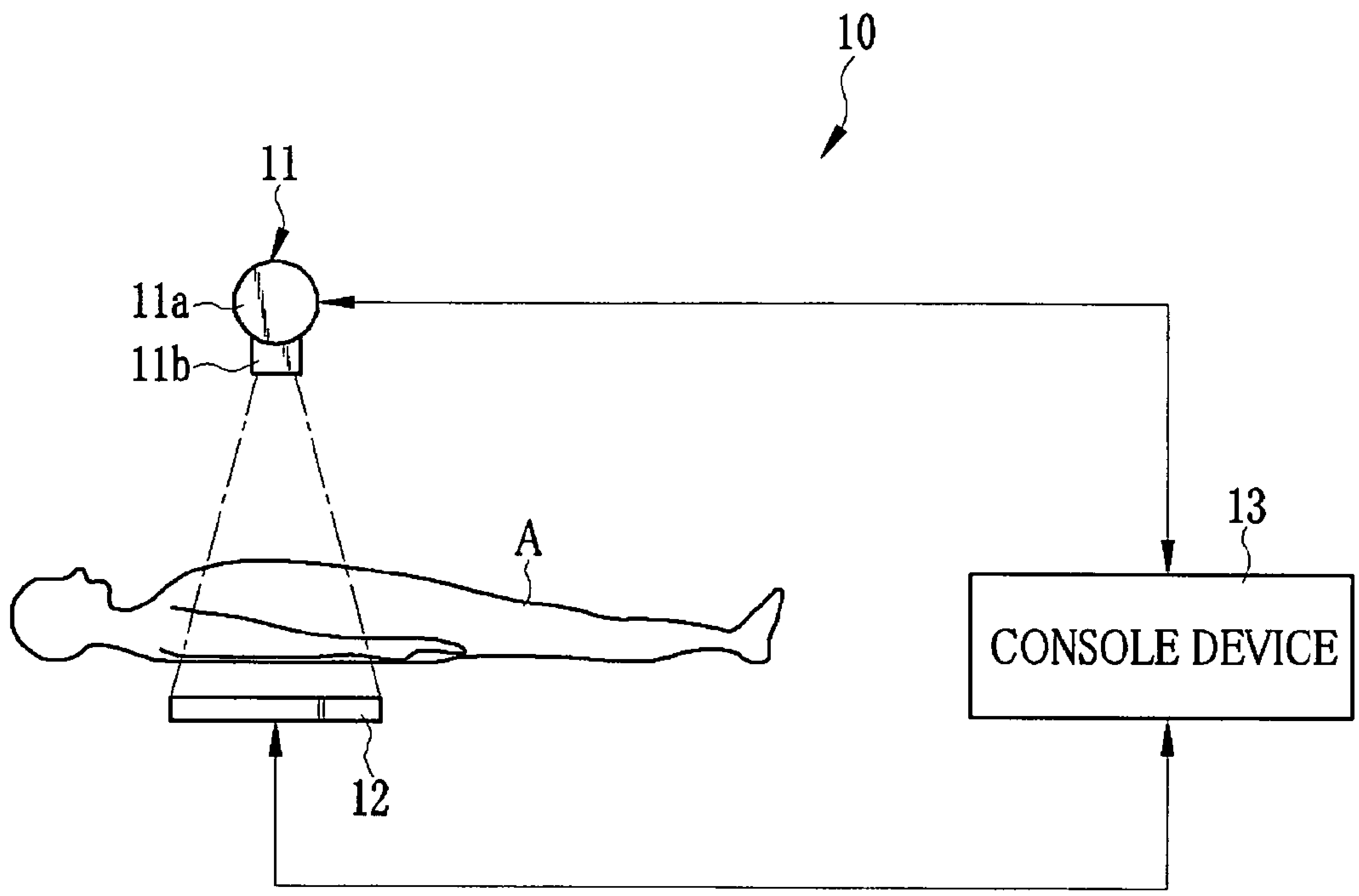


FIG. 2

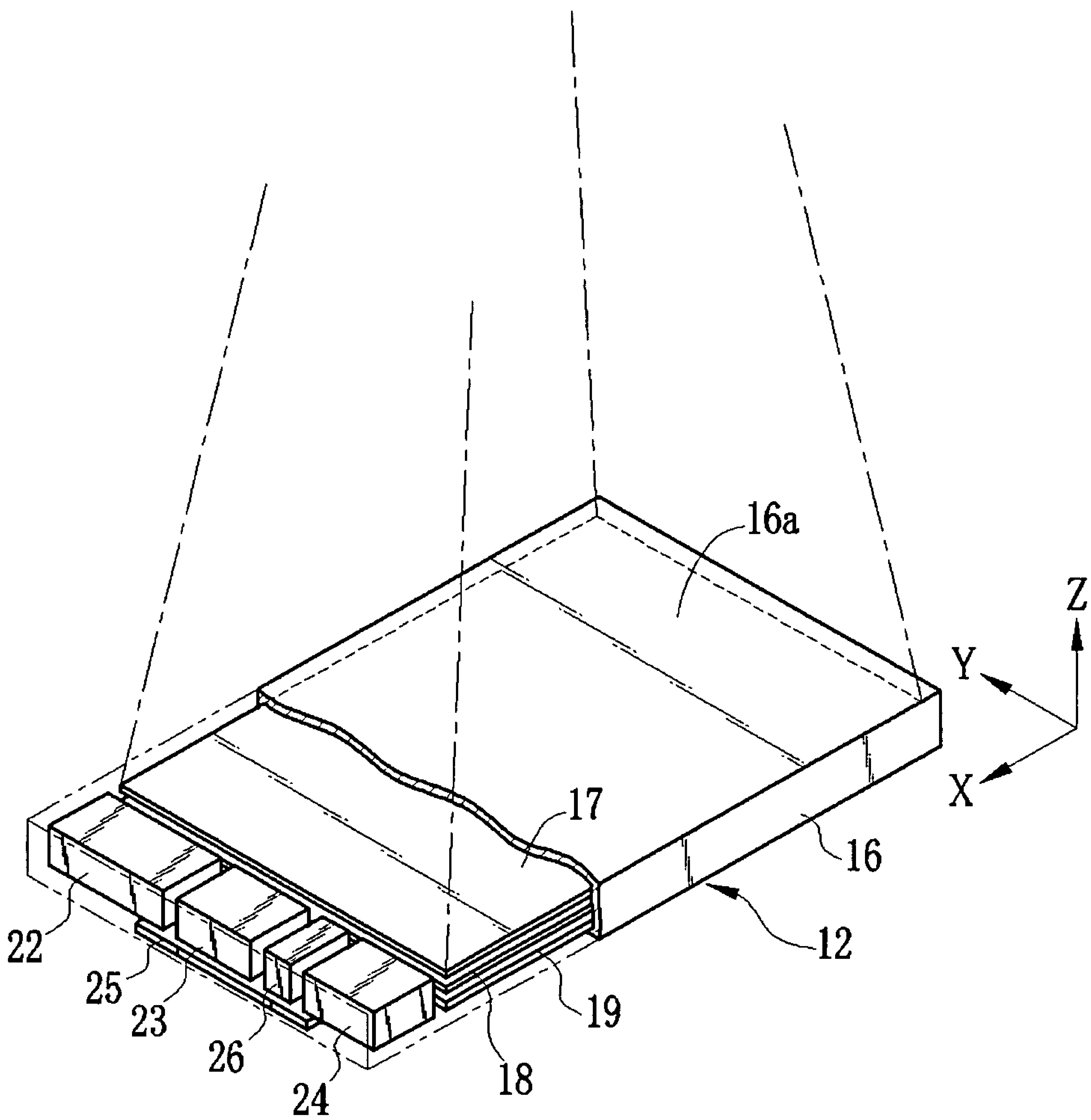


FIG. 3

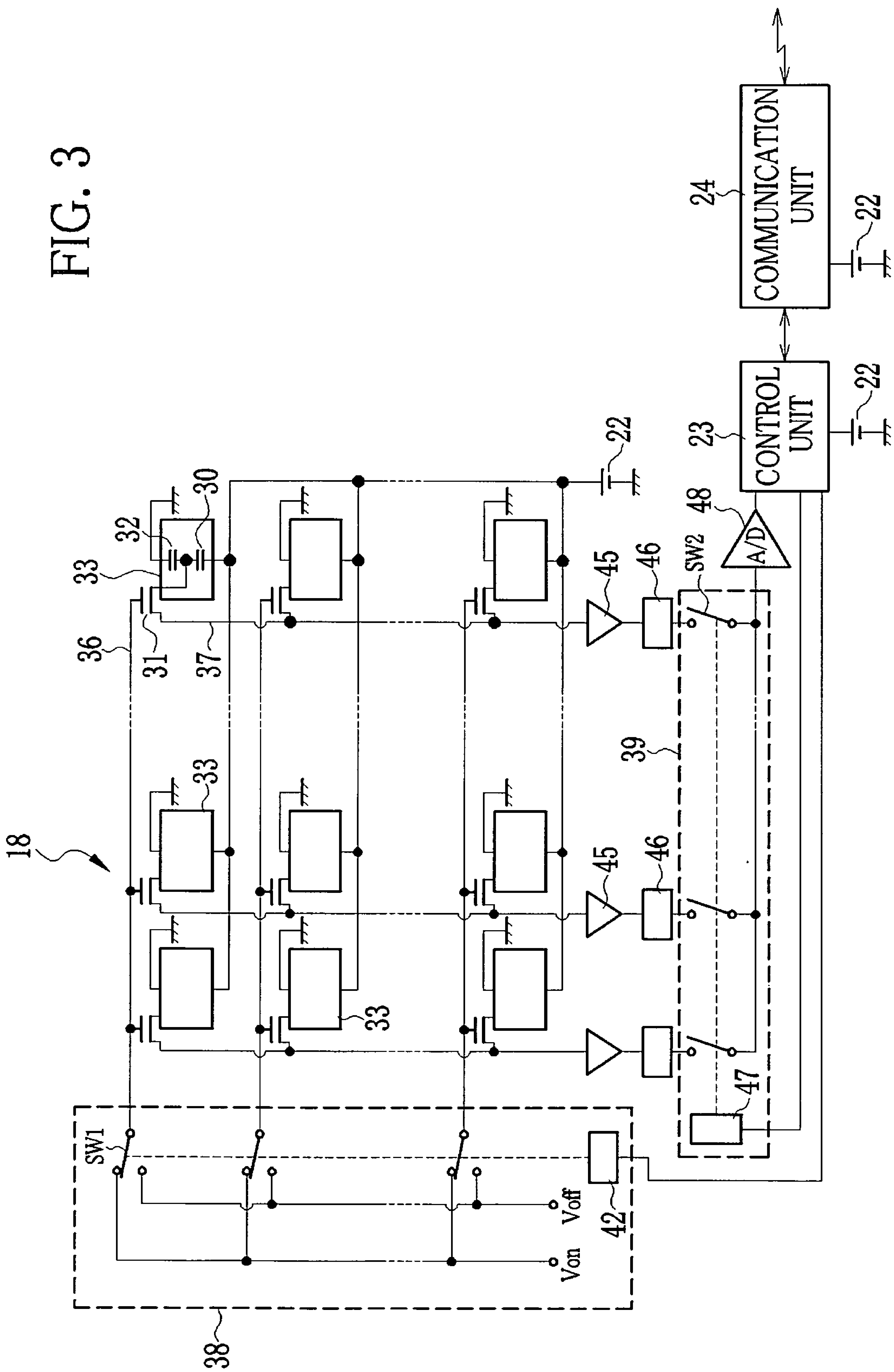

18
COMMUNICATION UNIT
24
22
CONTROL UNIT
23
22
22
30
32
33
36
31
37
33
33
45
46
SW2
48
A/D
39
45
46
47
SW1
42
Voff
Von
38

FIG. 4

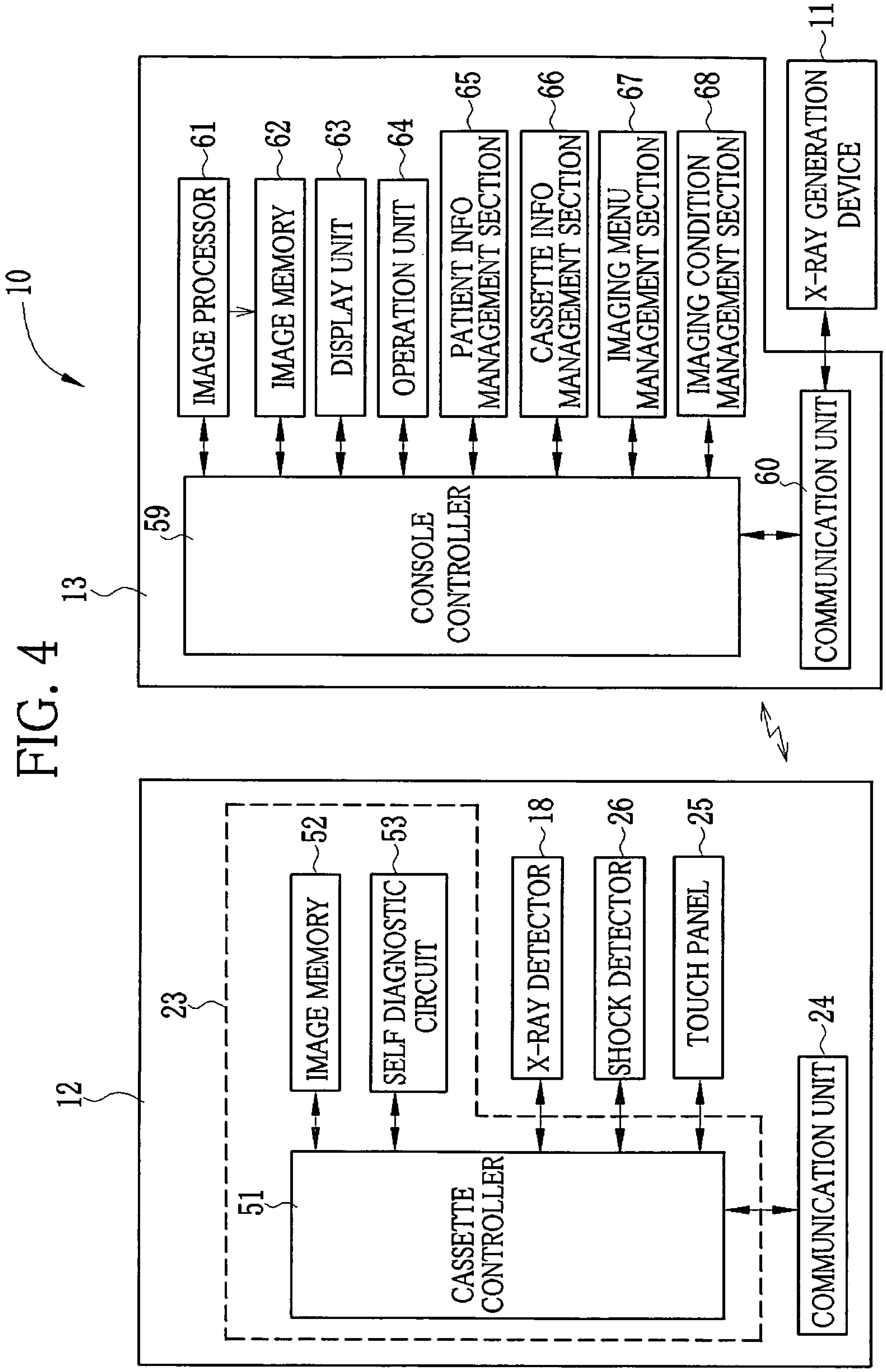

10
13
59
CONSOLE CONTROLLER
61
IMAGE PROCESSOR
62
IMAGE MEMORY
63
DISPLAY UNIT
64
OPERATION UNIT
65
PATIENT INFO MANAGEMENT SECTION
66
CASSETTE INFO MANAGEMENT SECTION
67
IMAGING MENU MANAGEMENT SECTION
68
IMAGING CONDITION MANAGEMENT SECTION
60
COMMUNICATION UNIT
11
X-RAY GENERATION DEVICE
12
23
51
CASSETTE CONTROLLER
52
IMAGE MEMORY
53
SELF DIAGNOSTIC CIRCUIT
18
X-RAY DETECTOR
26
SHOCK DETECTOR
25
TOUCH PANEL
24
COMMUNICATION UNIT

FIG. 5

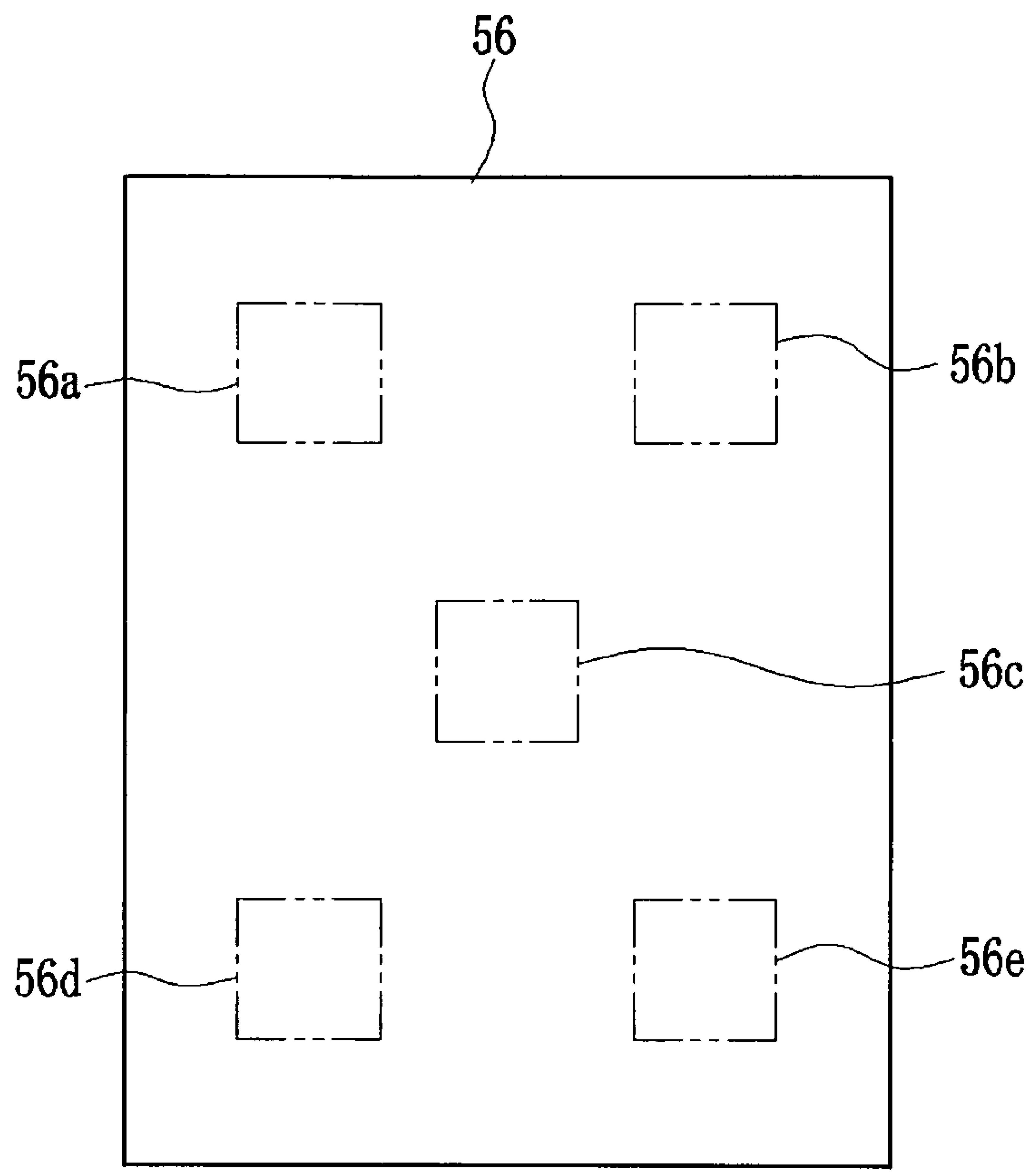


FIG. 6

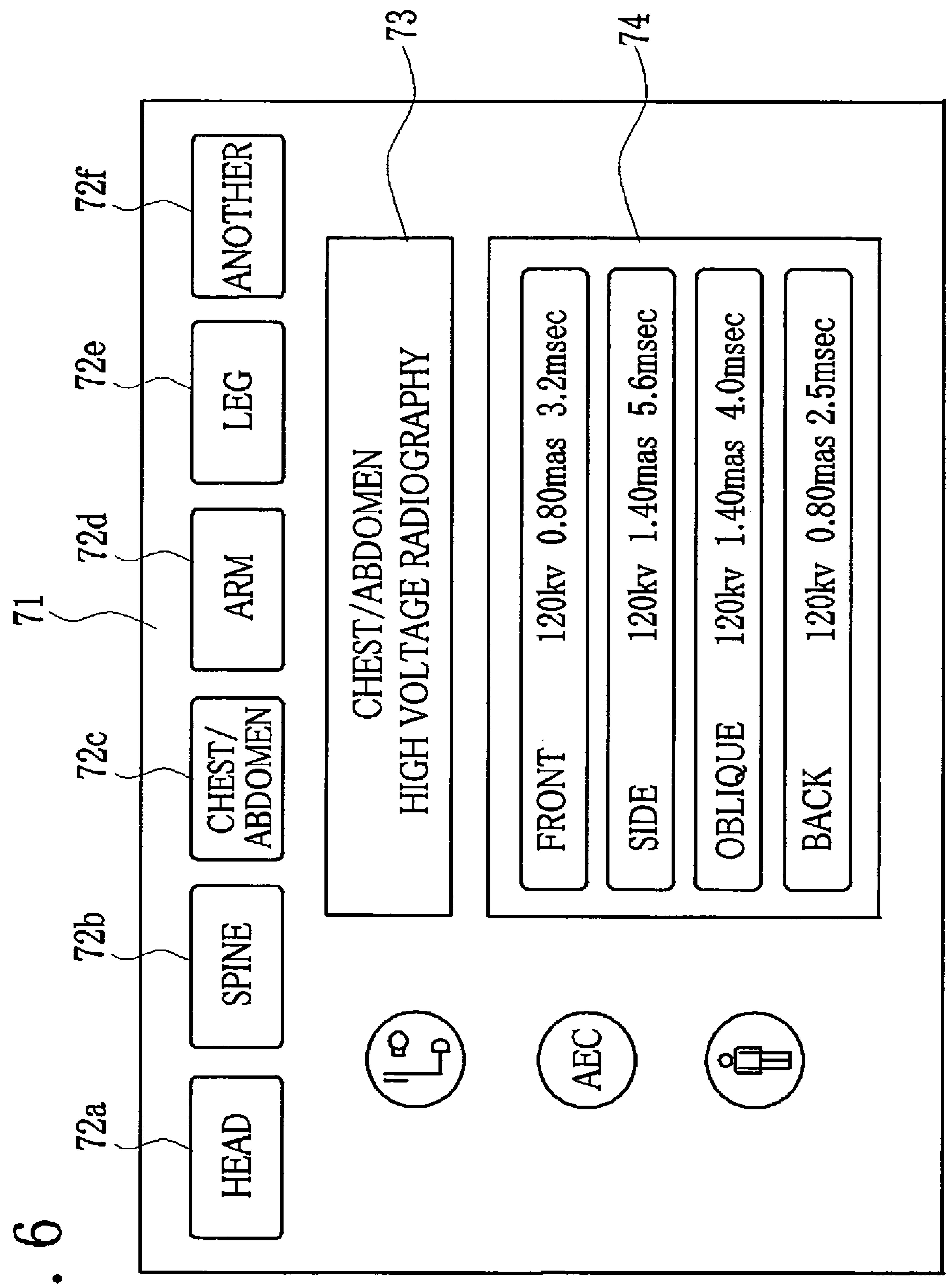

71
72a
72b
72c
72d
72e
72f
HEAD
SPINE
CHEST/ ABDOMEN
ARM
LEG
ANOTHER
73
CHEST/ABDOMEN
HIGH VOLTAGE RADIOGRAPHY
74
FRONT 120kv 0.80mas 3.2msec
SIDE 120kv 1.40mas 5.6msec
OBLIQUE 120kv 1.40mas 4.0msec
BACK 120kv 0.80mas 2.5msec
AEC

FIG. 7

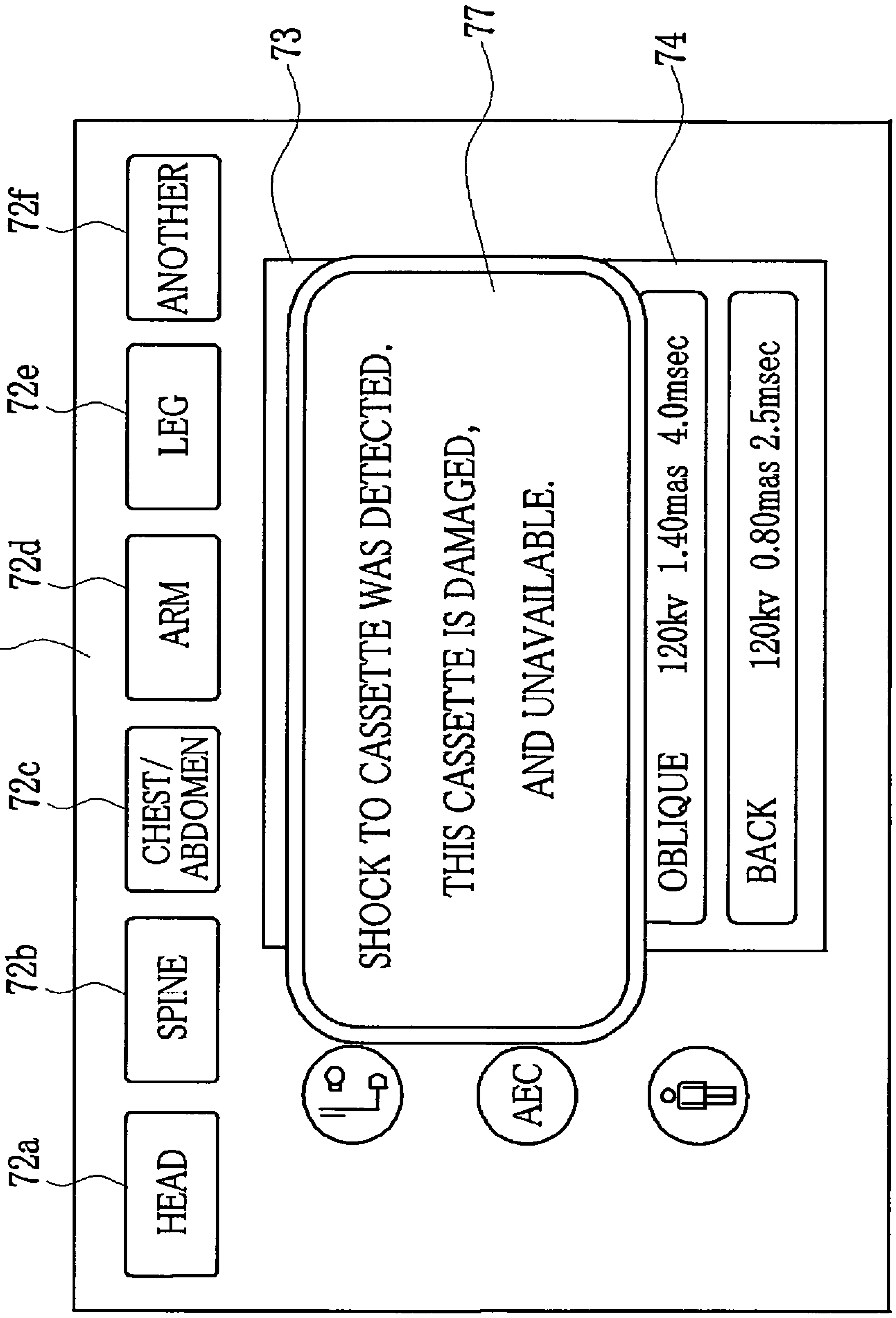

71
72a
72b
72c
72d
72e
72f
73
74
77
HEAD
SPINE
CHEST/ ABDOMEN
ARM
LEG
ANOTHER
SHOCK TO CASSETTE WAS DETECTED.
THIS CASSETTE IS DAMAGED,
AND UNAVAILABLE.
OBLIQUE 120kv 1.40mas 4.0msec
BACK 120kv 0.80mas 2.5msec
AEC

FIG. 8

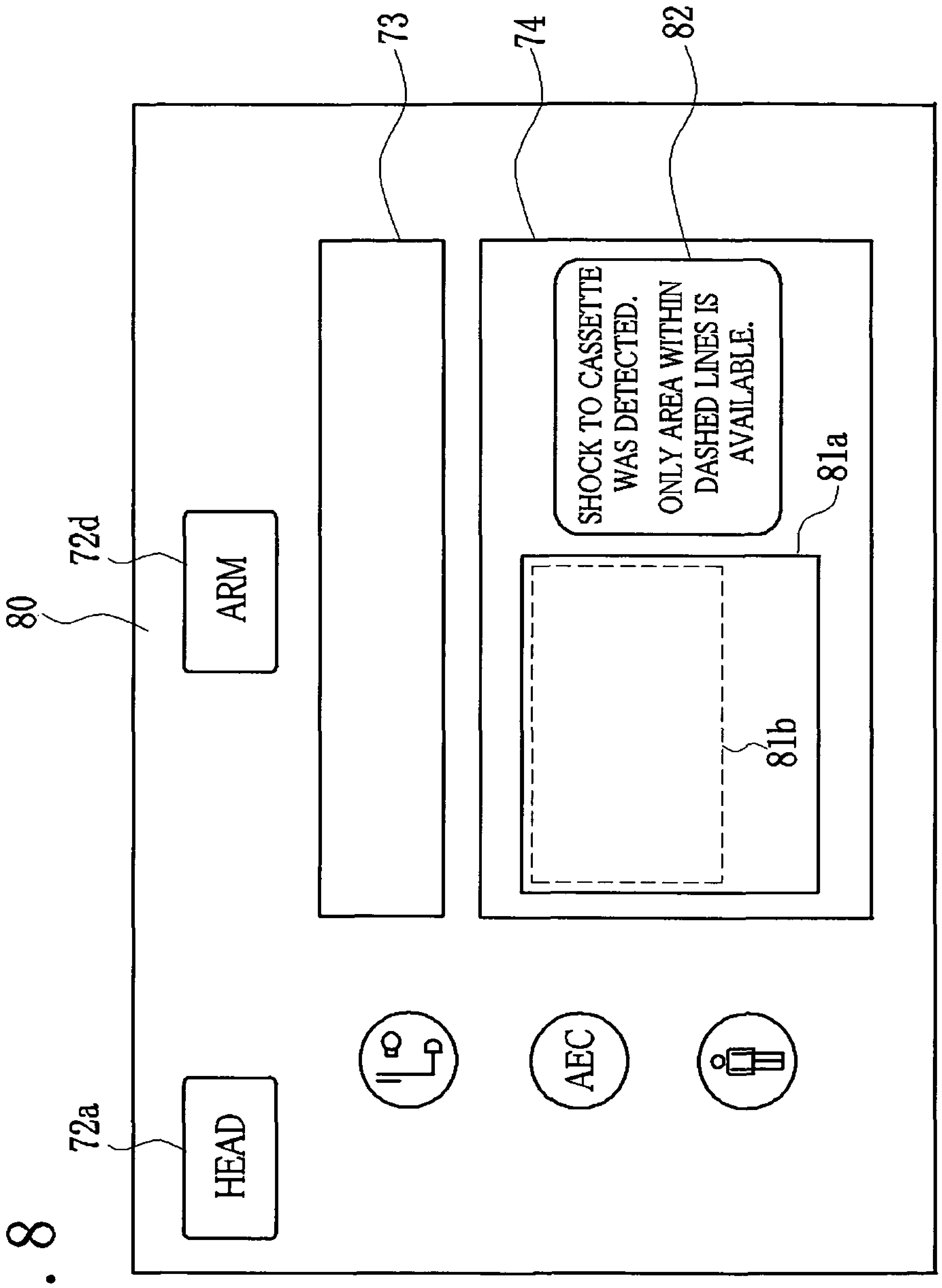

80
72d
ARM
72a
HEAD
73
74
82
SHOCK TO CASSETTE WAS DETECTED. ONLY AREA WITHIN DASHED LINES IS AVAILABLE.
81a
81b
AEC

FIG. 9

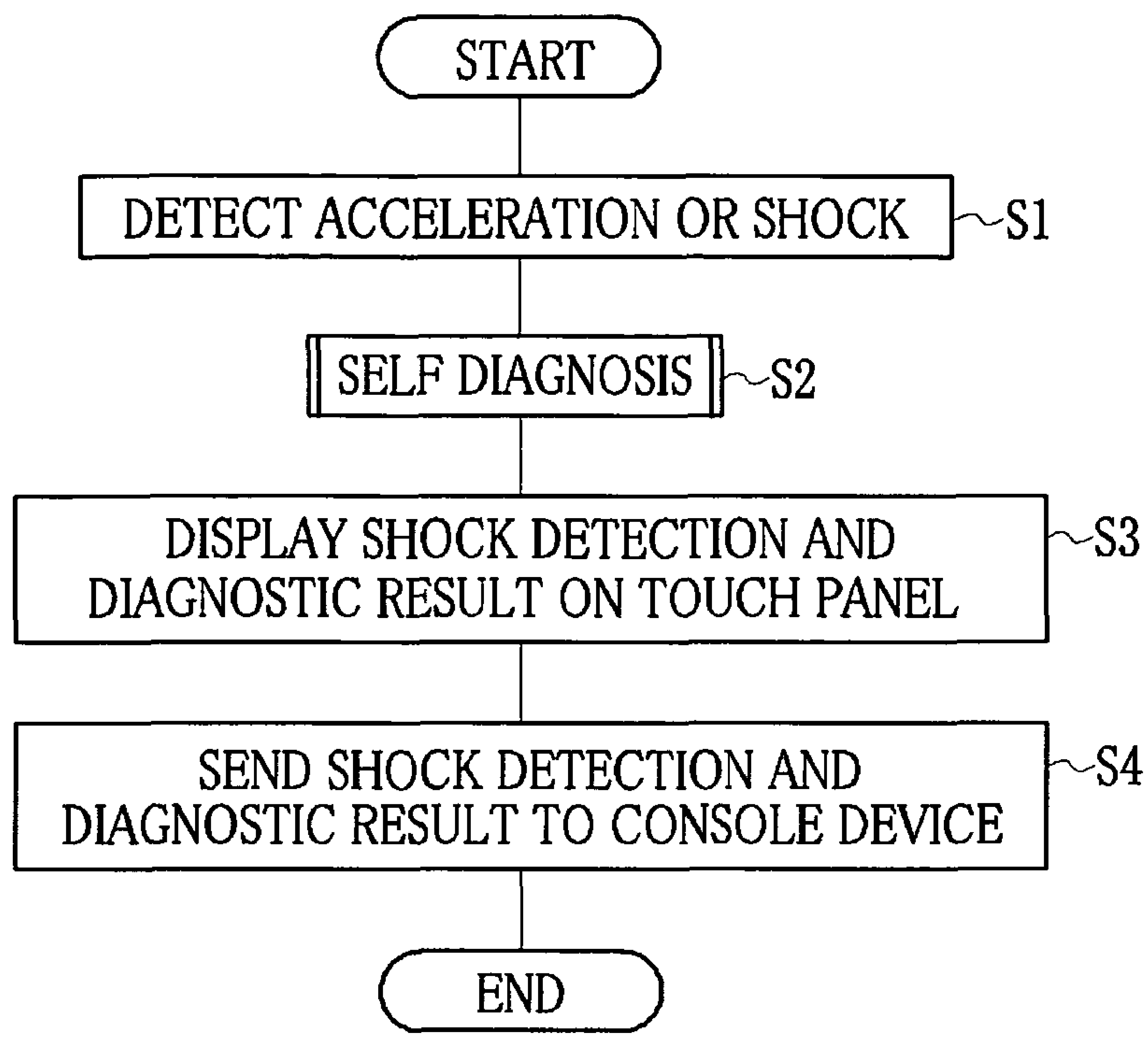

START
DETECT ACCELERATION OR SHOCK
S1
SELF DIAGNOSIS
S2
DISPLAY SHOCK DETECTION AND DIAGNOSTIC RESULT ON TOUCH PANEL
S3
SEND SHOCK DETECTION AND DIAGNOSTIC RESULT TO CONSOLE DEVICE
S4
END

FIG. 10

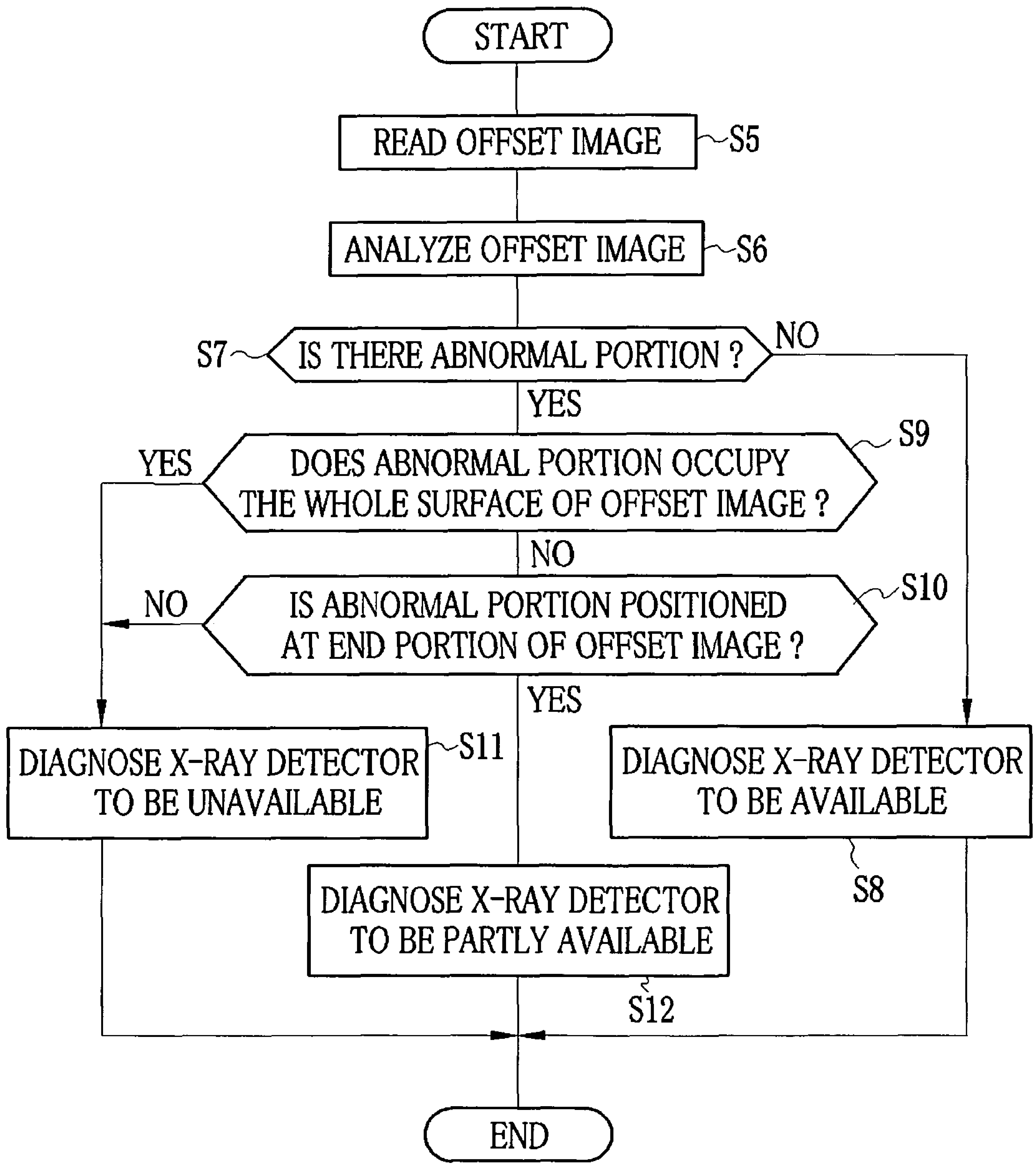

START
READ OFFSET IMAGE
S5
ANALYZE OFFSET IMAGE
S6
S7
IS THERE ABNORMAL PORTION ?
NO
YES
DOES ABNORMAL PORTION OCCUPY THE WHOLE SURFACE OF OFFSET IMAGE ?
S9
YES
NO
IS ABNORMAL PORTION POSITIONED AT END PORTION OF OFFSET IMAGE ?
S10
NO
YES
DIAGNOSE X-RAY DETECTOR TO BE UNAVAILABLE
S11
DIAGNOSE X-RAY DETECTOR TO BE AVAILABLE
S8
DIAGNOSE X-RAY DETECTOR TO BE PARTLY AVAILABLE
S12
END

FIG. 11

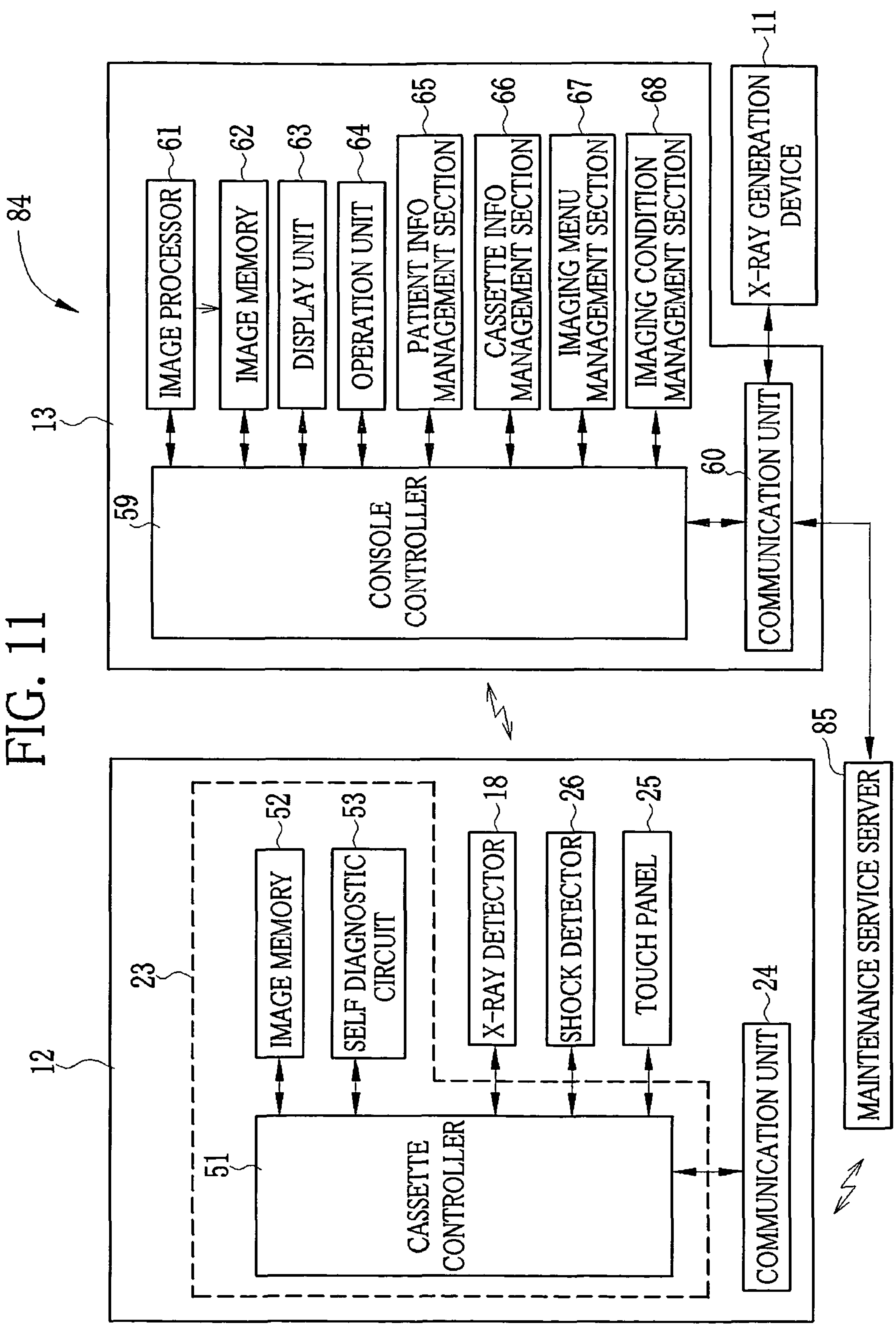

84
13
IMAGE PROCESSOR
61
IMAGE MEMORY
62
DISPLAY UNIT
63
OPERATION UNIT
64
PATIENT INFO MANAGEMENT SECTION
65
CASSETTE INFO MANAGEMENT SECTION
66
IMAGING MENU MANAGEMENT SECTION
67
IMAGING CONDITION MANAGEMENT SECTION
68
X-RAY GENERATION DEVICE
11
59
CONSOLE CONTROLLER
60
COMMUNICATION UNIT
85
MAINTENANCE SERVICE SERVER
12
23
IMAGE MEMORY
52
SELF DIAGNOSTIC CIRCUIT
53
X-RAY DETECTOR
18
SHOCK DETECTOR
26
TOUCH PANEL
25
51
CASSETTE CONTROLLER
COMMUNICATION UNIT
24

FIG. 12

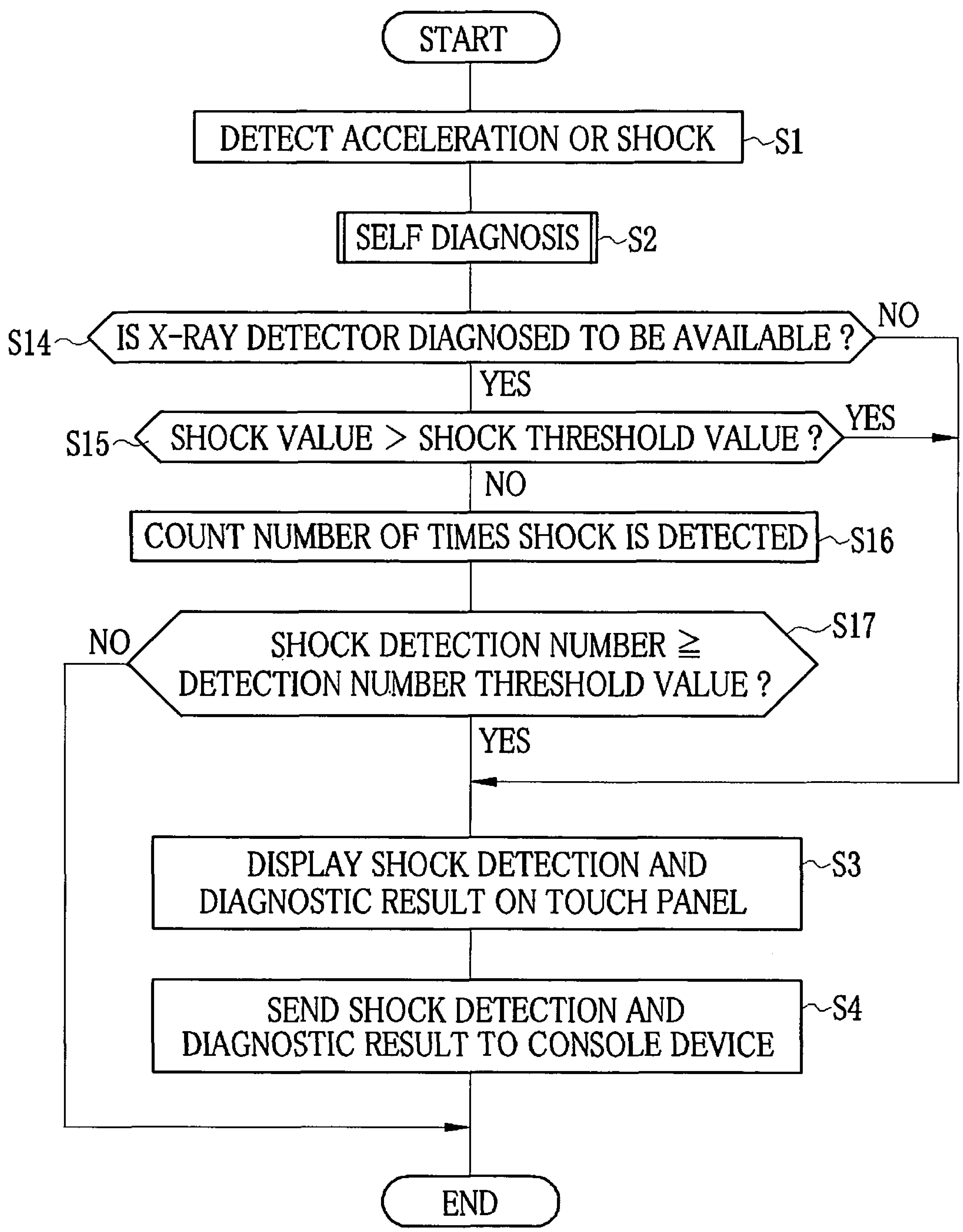
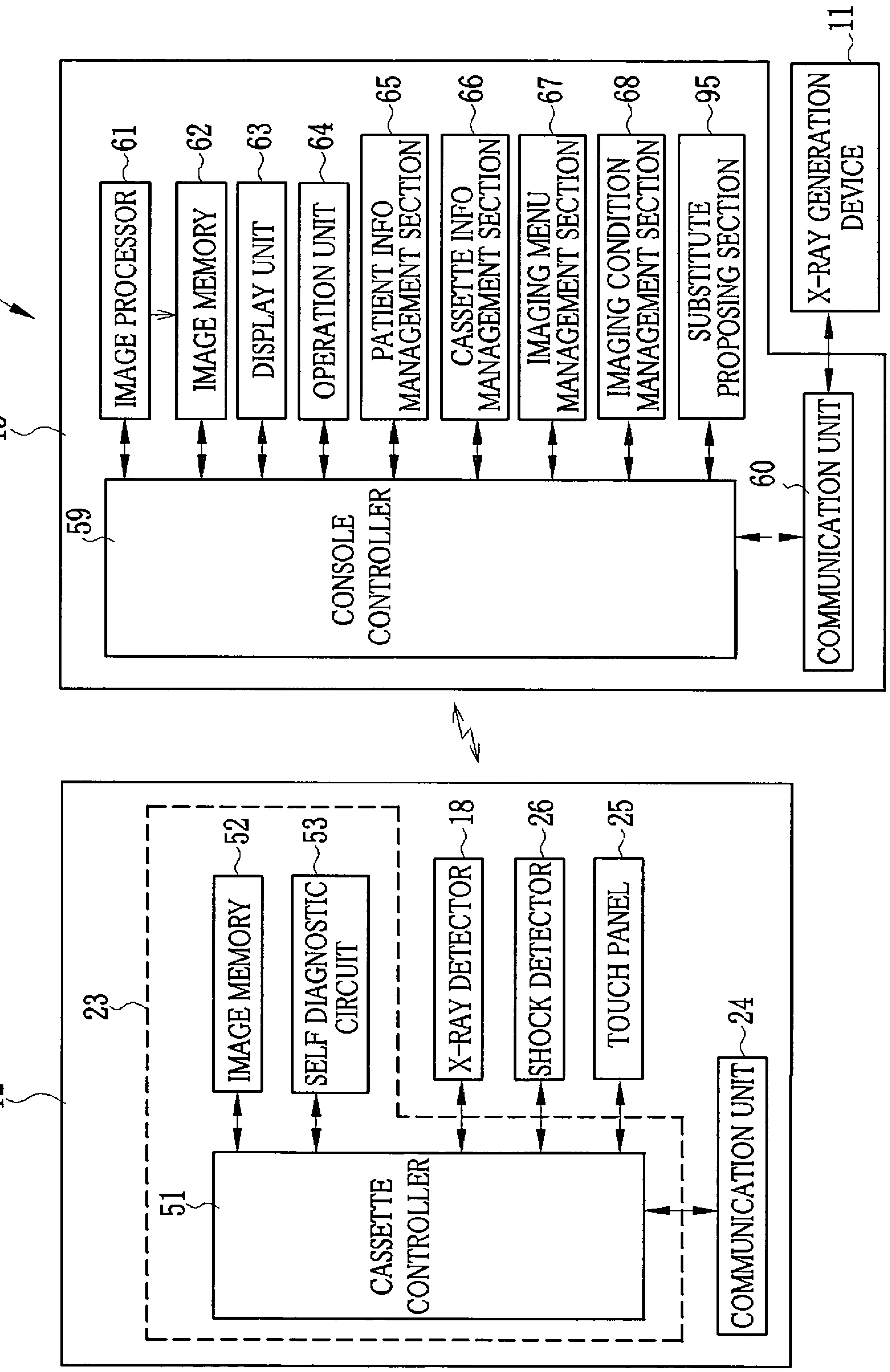

START
DETECT ACCELERATION OR SHOCK
S1
SELF DIAGNOSIS
S2
IS X-RAY DETECTOR DIAGNOSED TO BE AVAILABLE ?
S14
NO
YES
SHOCK VALUE > SHOCK THRESHOLD VALUE ?
S15
YES
NO
COUNT NUMBER OF TIMES SHOCK IS DETECTED
S16
SHOCK DETECTION NUMBER ≧ DETECTION NUMBER THRESHOLD VALUE ?
S17
NO
YES
DISPLAY SHOCK DETECTION AND DIAGNOSTIC RESULT ON TOUCH PANEL
S3
SEND SHOCK DETECTION AND DIAGNOSTIC RESULT TO CONSOLE DEVICE
S4
END

FIG. 13


94
13
IMAGE PROCESSOR
61
IMAGE MEMORY
62
DISPLAY UNIT
63
OPERATION UNIT
64
PATIENT INFO MANAGEMENT SECTION
65
CASSETTE INFO MANAGEMENT SECTION
66
IMAGING MENU MANAGEMENT SECTION
67
IMAGING CONDITION MANAGEMENT SECTION
68
SUBSTITUTE PROPOSING SECTION
95
X-RAY GENERATION DEVICE
11
59
CONSOLE CONTROLLER
60
COMMUNICATION UNIT
12
23
IMAGE MEMORY
52
SELF DIAGNOSTIC CIRCUIT
53
X-RAY DETECTOR
18
SHOCK DETECTOR
26
TOUCH PANEL
25
51
CASSETTE CONTROLLER
COMMUNICATION UNIT
24

RADIATION DETECTION DEVICE, IMAGING CONTROL DEVICE, RADIATION IMAGING SYSTEM, AND SELF DIAGNOSTIC METHOD OF RADIATION DETECTION DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority from Japanese Patent Application No. 2009-220290, filed Sep. 25, 2009, the contents of which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a radiation detection device having a radiation detector such as a flat panel detector contained in a cassette casing, and a radiation imaging apparatus including this radiation detection device, a consol device, and the like.

2. Description Related to the Prior Art

In a medical field, a radiation imaging apparatus for diagnostic imaging, e.g. an X-ray imaging apparatus that uses an X-ray as a radiation is widely known. The X-ray imaging apparatus is constituted of an X-ray generation device for applying an X-ray beam to a patient's body part to be examined, and an X-ray detection device for detecting the X-ray beam that has passed through the patient's body part. As the X-ray detection device, a cassette containing an imaging plate (IP) instead of an X-ray film, and a flat panel detector (FPD) are used in recent years. The IP has photostimulable storage phosphors for storing received radiation levels, and an X-ray image is produced by reading the IP with a specific laser scanner. The FPD, on the other hand, converts the received X-ray beam into signal charges, and produces the X-ray image in real time. Furthermore, a cassette-type FPD, in which the FPD is contained in a casing of the same shape and size as those of the cassette of the X-ray film or the IP, is recently developed so that the cassette-type FPD is loaded on the conventional X-ray imaging apparatus, instead of the X-ray film cassette.

The cassette-type FPD is frequently carried about because of being shared among a plurality of X-ray imaging apparatuses, or often moved with the portable X-ray imaging apparatus for use in radiography in a consulting room or a sick room. The frequent carriage increases the possibility of a break of the FPD by dropping or bumping the cassette-type FPD during the carriage.

To prevent use of the broken cassette-type FPD, for example, according to Japanese Patent Laid-Open Publication No. 2005-177379, the cassette-type FPD has a shock detection circuit and a self diagnostic circuit. In this cassette-type FPD, when the shock detection circuit detects a shock, the self diagnostic circuit is actuated to detect the presence of a failure. Also, in U.S. Pat. No. 7,514,703, the cassette-type FPD has an accelerometer. When the accelerometer detects an abnormal acceleration, electric power feeding to every part is stopped.

In the Japanese Patent Laid-Open Publication No. 2005-177379, the self diagnostic circuit diagnoses whether or not the cassette-type FPD is workable. However, even if the cassette-type FPD is workable, the image quality of the X-ray image is sometimes degraded to a level insufficient for a medical diagnosis. The self diagnosis cannot ensure the image quality of the X-ray image. In the U.S. Pat. No. 7,514,703, the cassette-type FPD stops feeding the electric power

based on only the acceleration. Thus, whether or not the cassette-type FPD is broken, the FPD become unusable.

Furthermore, since the FPD is expensive, few medical institutions keep the extra cassette-type FPD on hand. Therefore, even if the cassette-type FPD is partly damaged, it is desirable to temporarily use the partly damaged cassette-type FPD as long as it can produce the X-ray image adequate for the medical diagnosis.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a radiation detection device, an imaging control device, a radiation imaging system, and a self diagnostic method of the radiation detection device that self-diagnose a failure of a radiation detector, and inform a radiologic technologist of an available part of the radiation detector if the radiation detector is partly damaged.

To achieve the above and other objects, a radiation detection device according to the present invention includes a radiation detector, a shock detector, a self diagnostic circuit, and a cassette casing for containing the radiation detector, the shock detector, and the self diagnostic circuit. The radiation detector has a plurality of pixels that convert a radiation into signal charges and accumulate the signal charges. The signal charges accumulated in the individual pixels during an entry of the radiation are read out as an image signal of a radiographic image. The shock detector detects a shock given to the radiation detector. The self diagnostic circuit analyzes an offset image in response to detection of the shock by the shock detector to diagnose whether or not the radiation detector is available. The offset image is formed from the signal charges accumulated in the individual pixels of the radiation detector after the shock detection without the entry of the radiation.

It is preferable that the self diagnostic circuit analyzes the offset image, and finds out an abnormal portion in the offset image, and diagnoses whether or not the radiation detector is available based on the size or position of the abnormal portion.

The self diagnostic circuit may analyze at least one of a pixel value, a noise level, a point defect, and a line defect of the offset image.

If the offset image has no abnormal portion, the self diagnostic circuit diagnoses that the radiation detector is available. If the abnormal portion occupies a whole surface of the offset image or is positioned in a middle of the offset image, the self diagnostic circuit diagnoses that the radiation detector is unavailable. If the abnormal portion is positioned at an end portion of the offset image, the self diagnostic circuit diagnoses that the radiation detector is partly available.

The radiation detection device may further include a display unit for displaying the shock detection and a diagnostic result. When the radiation detector is unavailable or partly available, the display unit may carry out display operation, if a magnitude of the shock is a shock threshold value or more, or the number of times the shock is detected is a detection number threshold value or more.

The radiation detection device may further include a sending unit for sending the shock detection and the diagnostic result, or the shock detection and the offset image to outside. When the radiation detector is unavailable or partly available, the sending unit may carry out sending operation, if the magnitude of the shock is the shock threshold value or more, or the number of times the shock is detected is the detection number threshold value or more.

An imaging control device for controlling a radiation detection device according to the present invention includes a receiving unit and a controller. The receiving unit receives the shock detection and the diagnostic result from the sending unit. The controller permits or bans use of the radiation detection device in accordance with the diagnostic result.

The controller permits the use of the radiation detection device, if the diagnostic result indicates that the radiation detection device is available or partly available. The controller bans the use of the radiation detection device, if the diagnostic result indicates that the radiation detection device is unavailable.

The imaging control device may further include a display unit for indicating a usable area of the radiation detection device, if the radiation detection device is diagnosed to be partly available.

The imaging control device may further include an imaging menu management section for switching display of an imaging menu to choose a body part to be imaged in accordance with the diagnostic result.

The imaging menu management section may make all body parts to be imaged choosable, if the radiation detection device is diagnosed to be available. The imaging menu management section may change the choosable body part to be imaged in accordance with the usable area, if the radiation detection device is diagnosed to be partly available.

The imaging control device may further include a cassette information management section and a substitute proposing section. The cassette information management section stores and manages information of a plurality of radiation detection devices. If one of the radiation detection devices is diagnosed to be unavailable or partly available, the substitute proposing section proposes use of another one of the radiation detection devices the information of which is stored in the cassette information management section.

A radiation imaging system according to the present invention includes a radiation generation device for applying a radiation to an object, a radiation detection device, and an imaging control device for controlling the radiation generation device and the radiation detection device. The radiation detection device includes a radiation detector, a shock detector, a self diagnostic circuit, and a portable cassette casing. The radiation detector has a plurality of pixels for converting the radiation into the signal charges and accumulating the signal charges. The signal charges accumulated in the individual pixels during an entry of the radiation are read out as an image signal of a radiographic image. The shock detector detects a shock that is given to the radiation detector. The self diagnostic circuit analyzes the offset image in response to the shock detection by the shock detector to diagnose whether or not the radiation detector is available. The cassette casing contains the radiation detector, the shock detector, and the self diagnostic circuit.

The imaging control system may further include a maintenance device. The maintenance device has a judgment function and a communication unit. The judgment function precisely judges from the offset image whether or not the radiation detector is available. The communication unit sends the offset image and a judgment result to the radiation detection device or the imaging control device.

A self diagnostic method of the radiation detection device according to the present invention includes the steps of detecting the shock given to the radiation detection device; just after detection of the shock, reading out as the offset image the signal charges accumulated in the individual pixels of the radiation detection device without the entry of the radiation; and analyzing the offset image, and diagnosing whether or not the radiation detection device is available.

The diagnosing step may include the steps of analyzing the offset image and finding out the abnormal portion occurring in the offset image; and diagnosing whether or not the radiation detection device is available based on the size or position of the abnormal portion.

In the diagnosing step, if the offset image has no abnormal portion, the radiation detection device may be diagnosed to be available. If the abnormal portion occupies the whole surface of the offset image or is positioned in the middle of the offset image, the radiation detection device may be diagnosed to be unavailable. If the abnormal portion is positioned at the end portion of the offset image, the radiation detection device may be diagnosed to be partly available.

According to the present invention, whether the radiation detector is available, partly available, or unavailable is diagnosed based on the size or position of the abnormal portion occurring in the offset image. Thus, it is possible to certainly grasp a state of damage to the radiation detector. Even if apart of the radiation detector is damaged, radiography is smoothly carried out with use of a usable area, which works properly.

BRIEF DESCRIPTION OF THE DRAWINGS

For more complete understanding of the present invention, and the advantage thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a schematic view of an X-ray imaging apparatus;

FIG. **2** is a perspective view of a cassette-type X-ray detection device;

FIG. **3** is a circuit diagram of the X-ray detection device;

FIG. **4** is a block diagram of the X-ray imaging apparatus according to a first embodiment;

FIG. **5** is an explanatory view showing an example of an offset image;

FIG. **6** is an explanatory view showing an example of a normal imaging menu displayed on a monitor;

FIG. **7** is an explanatory view showing an example of an unavailability message displayed on the monitor;

FIG. **8** is an explanatory view showing an example of a temporary imaging menu displayed on the monitor;

FIG. **9** is a flowchart in detecting acceleration or shock;

FIG. **10** is a flowchart of a self diagnosis;

FIG. **11** is a block diagram of an X-ray imaging apparatus according to a second embodiment;

FIG. **12** is a flowchart in detecting acceleration or shock according to a third embodiment; and

FIG. **13** is a block diagram of an X-ray imaging apparatus according to a fourth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

As shown in FIG. **1**, an X-ray imaging apparatus **10** is constituted of an X-ray generation device **11** that applies an X-ray beam (shown by alternate long and short dash lines in FIG. **1**) to a patient's body A, a cassette-type X-ray detection device (hereinafter simply called cassette) **12** that receives the X-ray beam having passed through the patient's body A, and a consol device **13** that controls the X-ray generation device **11** and the cassette **12**. The X-ray generation device **11** and the cassette **12** are set up inside a radiation shielded chamber or a radiation room, and the console device **13** is set up outside the radiation shielded chamber.

The X-ray generation device **11** is constituted of an X-ray tube **11***a* for generating the X-ray beam, and a collimator **11***b* for limiting an irradiation field of the X-ray beam. The X-ray generation device **11** is movably supported by a support member. The X-ray generation device **11** is disposed so as to face the cassette **12**, and the irradiation field of the X-ray beam is variable in accordance with a patient's body part to be examined, which is chosen from the console device **13**.

Referring to FIG. **2**, the cassette **12** has the same shape and size as those of a conventional IP cassette, and is detachably loaded on an X-ray table or the like. As a matter of course, radiography is sometimes carried out with the cassette **12** making contact with the patient's body A. The cassette **12** is shared among a plurality of X-ray imaging apparatuses, and is sometimes brought out of the radiation shielded chamber together with the portable X-ray imaging apparatus for use in the radiography in a consulting room, a sickroom, or the like.

The cassette **12** is provided with a cassette casing **16** made of an X-ray transparent material. Inside the cassette casing **16**, a grid **17**, an X-ray detector **18**, and a lead plate **19** are disposed in this order from a side of an incident surface **16***a* of the cassette casing **16**. The grid **17** removes X-rays scattered from the patient's body A. The X-ray detector **18** detects the X-ray beam that has passed through the body part to be examined. The lead plate **19** absorbs the X-rays scattered backward.

The cassette casing **16** also contains a power source **22**, a control unit **23**, a communication unit **24**, a touch panel **25**, and a shock detector **26**. The power source **22** feeds electric power to each part of the cassette **12**. The control unit **23** controls operation of the X-ray detector **18**. The communication unit **24** communicates with the console device **13** by radio in order to send and receive various types of data including image data. The touch panel **25** is disposed on a surface opposite to the incident surface **16***a* to display various setting items and messages.

The shock detector **26** is composed of a triaxial accelerometer, for example, and detects and measures acceleration, inclination, shock, and the like applied to the cassette **12**. in triaxial directions along X, Y, and Z axes. Thus, it is detectable on which part the cassette **12** has fallen or bumped, and the magnitude of the shock due to the fall or bump. Although the fall or bump of the cassette **12** tends to occur while the cassette **12** is carried about, the cassette **12** is generally turned off during the carriage. Thus, the sock detector **26** is preferably supplied with the electric power and activated, even while the cassette **12** is turned off.

As shown in FIG. **3**, the X-ray detector **18** is constituted of an array of thin film transistors (TFTs) **31**, and photoelectric conversion layers **30** disposed on each TFT **31**. The photoelectric conversion layer **30** is made of amorphous selenium (a-Se), and converts the received X-rays into an electric charge. The electric charge generated by the photoelectric conversion layer **30** is accumulated in a capacitor **32**. Then, upon turning on the TFTs **31** on a row basis, the electric charges are read from the capacitors **32** as an X-ray image. In FIG. **3**, the connection between a single pixel **33** having the photoelectric conversion layer **30** and the capacitor **32** and the single TFT **31** is illustrated, though an illustration of the other pixels **33** is omitted.

A source of each TFT **31** is connected to the pixel **33**. A gate of each TFT **31** is connected to a gate line **36** extending in a row direction, and a drain of each TFT **31** is connected to a signal line **37** extending in a column direction. The gate lines **36** are connected to a line scanning driver **38**. The signal lines **37** are connected to a multiplexer **39**, which composes a readout circuit.

To each gate line **36**, the line scanning driver **38** applies a control voltage V_{on}/V_{off} to turn on or off the TFTs **31** aligned in the row direction. In this case, the line scanning driver **38** is provided with a plurality of switches SW**1** for switching the control voltage applied to each gate line **36** between V_{on} and V_{off}, and address decoder **42** that outputs a selection signal for selecting one of the plurality of switches SW**1**. To the address decoder **42**, the control unit **23** supplies an address signal.

When the application of the control voltage V_{on} turns on the TFTs **31** in the single row, the electric charges accumulated in the capacitors **32** of the pixels **33** in that row flow into the signal lines **37**. The electric charges read through the individual signal lines **37** are amplified by amplifiers **45**. The amplifiers **45** are connected to the multiplexer **39** through sample holding circuits **46**. The multiplexer **39** has a plurality of switches SW**2** for switching among the signal lines **37**, and an address decoder **47** that outputs a selection signal for selecting one of the plurality of switches SW**2**. To the address decoder **47**, the control unit **23** supplies an address signal. The multiplexer **39** is connected to an analog-to-digital converter (A/D) **48**. Accordingly, digital-format image data that is converted by the A/D **48** is supplied to the control unit **23**.

As shown in FIG. **4**, the control unit **23** of the cassette **12** is provided with a cassette controller **51**, an image memory **52**, and a self diagnostic circuit **53**. The cassette controller **51**, which overall controls each part of the cassette **12**, includes a CPU for carrying out various computing processes, a ROM for storing control programs executed by the CPU, a RAM for temporarily storing various types of data, and the like. The image memory **52** stores the image data outputted from the X-ray detector **18**.

In response to detection of the acceleration or the shock by the shock detector **26**, the self diagnostic circuit **53** reads from the X-ray detector **18** an offset image that is formed after the shock, and diagnoses whether the cassette **12** is available, partly available, or unavailable based on the offset image. The offset image is an image formed from signal charges accumulated by a dark current or the like in the capacitors **32** of the individual pixels **33** shown in FIG. **3** while no X-ray is detected. Analyzing the offset image allows determination of the presence or absence of damage to the pixels **33** and the like.

The self diagnostic circuit **53** analyzes the offset image, and identifies from an analysis result an abnormal portion of the offset image, that is, a portion different from a corresponding portion of the offset image obtained by the normal pixels **33**. The self diagnostic circuit **53** judges that the pixel **33** corresponding to the abnormal portion is damaged. In the analysis of the offset image, at least one of a pixel value, a noise level, a point defect, and a line defect is inspected, for example.

As for the analysis of the pixel value (also called QL value) of the offset image, every pixel value is checked to find out the pixel having the abnormal pixel value. Each pixel value should be stable, because the offset image is produced from the signal charges accumulated by the dark current of the X-ray detector **18**. Thus, finding out the pixel having the abnormal pixel value in the offset image allows determination of the damaged pixel **33**.

As for the analysis of the noise level of the offset image, as shown in FIG. **5**, a root mean square value of density variations is calculated in each of measurement areas **56***a* to **56***e* located in, for example, four quadrants and the middle of an offset image **56**, to obtain an RMS granularity. Then, the RMS granularity of each of the measurement areas **56***a* to **56***e* is compared with a reference value, and is checked whether or not to be within a predetermined range. This analysis allows determination of whether or not the X-ray detector **18** can perform the radiography with the specified RMS granularity, and an area of the X-ray detector **18** that can perform the radiography with the specified RMS granularity.

As for the analysis of the point defect and the line defect, a point-shaped defect and a line-shaped defect are detected from the offset image. This detection result is compared with a latest defect map stored in advance, so as to confirm whether or not the number of the point defects or the line defects is abruptly increased in comparison with that of the defect map. The pixels **33** corresponding to the abruptly increased point defects or line defects are judged to be damaged. Since the X-ray detector **18** has a lot of pixels **33**, the point defect in which only one pixel has sensitivity different from that of the other pixels, and the line defect in which the all aligned pixels have abnormal sensitivity tend to occur. Thus, the X-ray detector **18** creates and stores the defect map, which indicates the position and the size of the point defect and the line defect, not only during manufacture but also at regular time intervals, in order to correct the point defect and the line defect of the X-ray image based on the defect map. This defect map is used in the analysis of the point defect and the line defect of the offset image.

When the cassette **12** is registered on the console device **13**, the self diagnostic circuit **53** takes and stores the latest defect map created by the consol device **13**, and compares with the defect map the point defect and the line defect detected in the offset image. This analysis allows determination of breakage of each pixel **33** in the X-ray detector **18** . The detection of the point defect and the line defect is also described in Japanese Patent Laid-Open Publication Nos. 2001-008198 and 2006-047077, for example.

In the analysis of the offset image, at least one of items including the pixel value, the noise level, the point defect, and the line defect is inspected, and an appropriate combination of the items or all of the items may be inspected. If the plurality of items are inspected, it is preferable to determine the abnormal portion of the offset image in accordance with general judgment of analysis results.

The self diagnostic circuit **53** judges that the X-ray detector **18** is available, if there is no abnormal portion in the offset image **56**. The self diagnostic circuit **53** judges that the X-ray detector **18** is unavailable, if the abnormal portion occupies the whole surface of the offset image **56**, or does not exist at an end portion of the offset image **56** because a usable area becomes narrow. The self diagnostic circuit **53** judges that the X-ray detector **18** is partly available, if the abnormal portion exists at the end portion of the offset image **56**. In a case where the X-ray detector **18** is judged to be partly available, the self diagnostic circuit **53** identifies the usable area thereof.

The shock detector **26** sends the shock detection to the cassette controller **51**, and the self diagnostic circuit **53** sends a diagnostic result to the cassette controller **51**. The cassette controller **51** displays the shock detection and the diagnostic result on the touch panel **25**, and sends the shock detection and the diagnostic result to the consol .device **13** via the communication unit **24**.

As shown in FIG. **4**, the console device **13** is provided with a console controller **59**, a communication unit **60**, an image processor **61**, an image memory **62**, a display unit **63**, an operation unit **64**, a patient information management section **65**, a cassette information management section **66**, an imaging menu management section **67**, an imaging condition management section **68**, and the like.

The console controller **59**, as with the cassette controller **51**, is composed of a CPU for carrying out computing processes, a ROM for storing control programs and control data, a RAM for temporarily storing various types of data, and the like, and overall controls every part of the console device **13**. The communication unit **60** sends and receives necessary information including the image data to and from the communication unit **24** and the X-ray generation device **11** by wired or wireless communication.

The image processor **61** applies various types of image processing to the image data received from the cassette **12**. The image memory **62** stores the image data after the image processing. The display unit **63** includes a monitor such as an LCD, and a display circuit for displaying the X-ray image, various operation screens such as an imaging menu, and the like. The operation unit **64** includes a keyboard, a mouse, and the like, and is used in various settings and operations. The operation unit **64** includes an exposure button. Upon pushing the exposure button, the X-ray beam is emitted from the X-ray generation device **11**, and the cassette **12** is actuated to capture the X-ray image.

The patient information management section **65** manages patients' information. The patients' information includes a name, a sex, an ID number, and the like of each patient, and is information to identify each patient. The cassette information management section **66** manages cassette information of each cassette **12** registered on the console device **13**. The cassette information includes an ID number of the cassette **12**, X-ray image correction data including the defect map obtained by calibration, and the diagnostic result by the self diagnostic circuit **53**. The console controller **59** refers to the cassette information before using the cassette **12**. If the cassette **12** is judged to be unavailable by the self diagnosis, the console controller **59** bans use of the cassette **12**.

The imaging menu management section **67** switches the imaging menu displayed on the display unit **63**, based on the diagnostic result registered on the cassette information management section **66**. The imaging menu is a menu for choosing the patient's body part to be examined among a head, a spine, a chest/abdomen, an arm, and a leg, for example.

If the cassette **12** is judged to be available by the self diagnosis, the imaging menu management section **67** displays a normal imaging menu **71** on the display unit **63**, as shown in FIG. **6**. This normal imaging menu **71** has choice buttons **72***a* to **72***f* from which every body part to be examined is choosable, and a choice box **73** for indicating the chosen body part to be examined, a submenu box **74** for choosing the direction of imaging the chosen body part to be examined, and the like.

If the cassette **12** is judge to be unavailable by the self diagnosis, the imaging menu management section **67** displays a message box **77** over the normal imaging menu **71**, as shown in FIG. **7**. The message box **77** says that the cassette **12** got a shock, and the shock damaged the cassette **12** and made the cassette **12** unavailable. At this time, operation on the normal imaging menu is preferably banned.

If the cassette **12** is judged to be partly available by the self diagnosis, the imaging menu management section **67** displays a temporary imaging menu **80** on the display unit **63**, as shown in FIG. **8**. In this temporary imaging menu **80**, rectangular solid lines **81***a* representing the whole area of the X-ray detector **18** and rectangular broken lines **81***b* representing the usable area of the X-ray detector **18** within the whole area are displayed in the submenu box **74**. In the submenu box **74**, there is also displayed a message **82** saying the cassette **12** got a shock and only a part of the cassette **12** is available. Furthermore, only the choice buttons of the body parts to be examined where the damaged X-ray detector **18** can image, e.g. the choice buttons **72***a* and **72***d* of the head and the arm are displayed. The number and the types of the displayed choice buttons depend on the usable area of the X-ray detector **18**.

The imaging condition management section **68** manages imaging conditions set up on the normal imaging menu **71** or the temporary imaging menu **80**. The imaging conditions include, for example, the body part to be examined, an imaging method, and the number of X-ray images to be photographed, and are conditions on which a tube voltage, a tube current, an application time, and the like are determined to apply the X-ray beam of an appropriate dose to the body part to be examined.

Next, the operation of the X-ray imaging apparatus **10** will be described with referring to a flowchart of FIG. **9**. If the cassette **12** is dropped or bumped during carriage, the shock detector **26** detects the acceleration or the shock (S**1**). A detection signal from the shock detector **26** is inputted to the cassette controller **51**. In response to the detection signal from the shock detector **26**, the cassette controller **51** makes the self diagnostic circuit **53** start the self diagnosis of the X-ray detector **18** (S**2**).

FIG. **10** shows a flowchart of the self diagnosis (S**2**). The self diagnostic circuit **53** reads the offset image **56** from the X-ray detector **18** (S**5**), and analyzes at least one of the pixel value, the noise level, the point defect, and the line defect of the offset image **56** (S**6**). The self diagnostic circuit **53** determines the size and the position of the abnormal portion in the offset image (S**7**), and judges whether or not the X-ray detector **18** is available.

If there is no abnormal portion in the offset image **56** (NO in S**7**), the self diagnostic circuit **53** judges that the X-ray detector **18** is available (S**8**). If the abnormal portion occupies the whole surface of the offset image **56** (YES in S**9**), or the abnormal portion is positioned in the middle of the offset image **56** (NO in S**10**), the self diagnostic circuit **53** judges that the X-ray detector **18** is unavailable (S**11**). If the abnormal portion is positioned at the end portion of the offset image **56** (YES in S**10**), the self diagnostic circuit **53** judges that the X-ray detector **18** is partly available (S**12**).

As shown in FIG. **9**, the cassette controller **51** displays that the cassette **12** got the shock and the diagnostic result on the touch panel **25** (S**3**). Thus, a radiological technologist is immediately notified of a state of the cassette **12** during the carriage. The cassette controller **51** sends the shock detection and the diagnostic result to the console device **13** via the communication unit **24** (S**4**).

The console controller **59** stores the diagnostic result of the cassette **12** in the cassette information management section **66**. The console controller **59** also displays the shock detection and the diagnostic result on the display unit **63**, in order to call attention to the radiological technologist who is carrying out the radiography with use of the cassette **12**.

In using the cassette **12**, the console controller **59** reads the diagnostic result of the cassette **12** from the cassette information management section **66**. If the cassette **12** is judged to be available, the imaging menu management section **67** displays on the display unit **63** the normal imaging menu **71** as shown in FIG. **6**. If the cassette **12** is judged to be unavailable, the imaging menu management section **67** displays on the display unit **63** the message box **77** as shown in FIG. **7**.

If the cassette **12** is judged to be partly available, the imaging menu management section **67** displays on the display unit **63** the temporary imaging menu **80** as shown in FIG. **8**. Thus, even if the cassette **12** is partly damaged, the cassette **12** is temporarily usable for the radiography. In the temporary imaging menu **80**, since the usable area of the X-ray detector **18** can be visually checked, the radiography is carried out with avoiding the use of a defective area of the X-ray detector **18**. Furthermore, since only the choice buttons corresponding to the body parts that can be examined are displayed, the use of the defective area of the X-ray detector **18** is prevented.

Second to fourth embodiments of the present invention will be described below. The same reference numerals as those of the first embodiment indicate the same components as those of the first embodiment, and detailed description thereof will be omitted.

Second Embodiment

If the X-ray imaging apparatus uses a remote maintenance service including operation assistance and damage diagnosis, a maintenance service server of that service may carry out a diagnosis of the cassette **12**. In an X-ray imaging apparatus **84** as shown in FIG. **11**, the communication unit **60** of the console device **13** is connected to a maintenance service server **85** through a network. The communication unit **24** of the cassette **12** sends the shock detection and the offset image to the maintenance service server **85**. The maintenance service server **85** analyzes the offset image with use of a CPU having higher performance than that of the cassette **12**, and diagnoses whether or not the cassette **12** is available. The diagnostic result is sent to the cassette **12**. Thus, the damage diagnosis is carried out more precisely and sophisticatedly.

In a case where the cassette **12** cannot be provided with a communication unit that is able to communicate with the maintenance service server **85**, the shock detection and the offset image may be sent from the communication unit **60** of the console device **13**. The cassette **12** or the console device **13** may automatically send the offset image and the like to the maintenance service server **85**, whenever the shock is detected, or after use of the X-ray imaging apparatus **84** of the day.

Third Embodiment

In the first embodiment, the shock detection and the diagnostic result are displayed on the touch panel **25** and the consol device **13**, when the shock detector **26** detects the shock. However, even though the cassette **12** is not damaged, the display of the shock detection and the diagnosis result is irksome, and may cause the cassette **12** to be mistaken for being damaged. Thus, if the self diagnosis circuit **53** judges that the cassette **12** is available, nothing is displayed except in a special case, while if the cassette **12** is judged to be unavailable, the shock detection and the diagnostic result are displayed on the touch panel **25** and the monitor of the console device **13**.

In the third embodiment, as shown in FIG. **12**, when the cassette **12** is judged to be available (YES in S**14**), the cassette controller **51** of the cassette **12** compares a shock value measured by the shock detector **26** with a predetermined shock threshold value (S**15**). The shock threshold value is a magnitude of shock that may cause damage to the cassette **12**. If the shock value is larger than the shock threshold value, the shock detection and the diagnostic result are displayed on the touch panel **25** (S**3**), and sent to the console device **13** (S**4**).

If the shock value is equal to or smaller than the shock threshold value, the cassette controller **51** counts the number of times the shock is detected (S**16**). When a shock detection number becomes equal to or exceeds a detection number threshold value, the shock detection and the diagnostic result are displayed on the touch panel **25** (S**3**), and sent to the consol device **13** (S**4**). The detection number threshold value is a number of counts from which the cassette **12** is likely to be damaged. The third embodiment can remove irksomeness due to the frequent display of the shock detection and the diagnostic result. When the possibility of damage of the cassette **12** is increased due to a significant magnitude of shock or a large number of shocks, the shock detection and the diagnostic result are displayed to call attention on the occurrence of damage.

Fourth Embodiment

When the cassette **12** that was intended to be used has been damaged and become unavailable or partly available, a substitute cassette may be proposed. In an X-ray imaging apparatus **94** as shown in FIG. **13**, the console device **13** is provided with a substitute proposing section **95**. If the diagnostic result that says the cassette **12** is unavailable or partly available is sent from the cassette **12**, the substitute proposing section **95** obtains information of another cassette registered on the console device **13** from the cassette information management section **66**, and displays a message suggesting use of the substitute cassette on the display unit **63**.

Therefore, the radiography is smoothly carried out even if the cassette **12** is damaged. The substitute cassette may be not only the cassette-type FPD but also an IP cassette or an X-ray film cassette. It is also preferable to notify the radiological technologist of a place where the substitute cassette is stored and the like.

In the above embodiments, if the X-ray beam is applied to the unusable area of the partly available X-ray detector **18**, a warning message for suggesting reshooting may be issued. The present invention is not limited to the above first to fourth embodiments, and includes appropriate combinations of the first to fourth embodiments. In the above embodiments, an X-ray is took as an example of radiation, but other types of radiation including a γ-ray and an α-ray are available instead of the X-ray.

Although the present invention has been fully described by the way of the preferred embodiment thereof with reference to the accompanying drawings, various changes and modifications will be apparent to those having skill in this field. Therefore, unless otherwise these changes and modifications depart from the scope of the present invention, they should be construed as included therein.

What is claimed is:

1. An x-ray radiation detection device comprising:

an x-ray radiation detector having a plurality of pixels for converting an x-ray radiation into signal charges and accumulating the signal charges, the signal charges accumulated in the individual pixels during an entry of the x-ray radiation being read out as an image signal of a radiographic image;

a shock detector for detecting a shock given to the x-ray radiation detector;

a self diagnostic circuit for analyzing an offset image in response to detection of the shock by the shock detector to diagnose whether or not the x-ray radiation detector is available, the offset image being formed from the signal charges accumulated in the individual pixels of the x-ray radiation detector after the shock detection without the entry of the x-ray radiation; and

a cassette casing for containing the x-ray radiation detector, the shock detector, and the self diagnostic circuit,

wherein the self diagnostic circuit analyzes the offset image, and finds out an abnormal portion in the offset image, and diagnoses whether or not the x-ray radiation detector is available based on a size or a position of the abnormal portion.

2. The x-ray radiation detection device according to claim **1**, wherein

on condition that the offset image has no abnormal portion, the self diagnostic circuit diagnoses that the x-ray radiation detector is available;

on condition that the abnormal portion occupies a whole surface of the offset image or is positioned in a middle of the offset image, the self diagnostic circuit diagnoses that the x-ray radiation detector is unavailable; and

on condition that the abnormal portion is positioned at an end portion of the offset image, the self diagnostic circuit diagnoses that the x-ray radiation detector is partly available.

3. The x-ray radiation detection device according to claim **1**, wherein the self diagnostic circuit analyzes at least one of a pixel value, a noise level, a point defect, and a line defect of the offset image.

4. The x-ray radiation detection device according to claim **3**, further comprising:

a display unit for displaying the shock detection and a diagnostic result.

5. The x-ray radiation detection device according to claim **4**, wherein when the x-ray radiation detector is unavailable or partly available, the display unit carries out display operation, when a magnitude of the shock is a shock threshold value or more, or a number of times the shock is detected is a detection number threshold value or more.

6. The x-ray radiation detection device according to claim **3**, further comprising:

a sending unit for sending the shock detection and a diagnostic result, or the shock detection and the offset image to outside.

7. The x-ray radiation detection device according to claim **6**, wherein when the x-ray radiation detector is unavailable or partly available, the sending unit carries out sending operation, when a magnitude of the shock is a shock threshold value or more, or a number of times the shock is detected is a detection number threshold value or more.

8. An x-ray radiation imaging system comprising:

A. an x-ray radiation generation device for applying an x-ray radiation to an object;

B. an x-ray radiation detection device including:

an x-ray radiation detector having a plurality of pixels for converting the x-ray radiation into signal charges and accumulating the signal charges, the signal charges accumulated in the individual pixels during an entry of the x-ray radiation being read out as an image signal of a radiographic image;

a shock detector for detecting a shock given to the x-ray radiation detector;

a self diagnostic circuit for analyzing an offset image in response to detection of the shock by the shock detector to diagnose whether or not the x-ray radiation detector is available, the offset image being formed from the signal charges accumulated in the individual pixels of the x-ray radiation detector after the shock detection without the entry of the x-ray radiation; and

a portable cassette casing for containing the x-ray radiation detector, the shock detector, and the self diagnostic circuit; and

C. an imaging control device for controlling the x-ray radiation generation device and the x-ray radiation detection device;

wherein the self diagnostic circuit analyzes the offset image, and finds out an abnormal portion in the offset image, and diagnoses whether or not the x-ray radiation detector is available based on a size or a position of the abnormal portion.

9. The x-ray radiation imaging system according to claim **8**, further comprising:

a maintenance device including:

a judgment function for precisely judging from the offset image whether or not the x-ray radiation detector is available; and

a communication unit for sending the offset image and a judgment result to the x-ray radiation detection device or the imaging control device.

10. A self diagnostic method of an x-ray radiation detection device, the x-ray radiation detection device having a plurality of pixels for converting an x-ray radiation into signal charges and accumulating the signal charges, the signal charges accumulated in the individual pixels during an entry of the x-ray radiation being read out as a radiographic image, the self diagnostic method comprising the steps of:

detecting a shock given to the x-ray radiation detection device;

just after detection of the shock, reading out as an offset image the signal charges accumulated in the individual pixels of the x-ray radiation detection device without the entry of the x-ray radiation;

analyzing the offset image and finding out an abnormal portion occurring in the offset image; and

diagnosing whether or not the x-ray radiation detection device is available based on a size or a position of the abnormal portion.

11. The self diagnostic method according to claim **10**, wherein in the diagnosing step,

on condition that the offset image has no abnormal portion, the x-ray radiation detection device is diagnosed to be available;

on condition that the abnormal portion occupies a whole surface of the offset image or is positioned in a middle of the offset image, the x-ray radiation detection device is diagnosed to be unavailable; and

on condition that the abnormal portion is positioned at an end portion of the offset image, the x-ray radiation detection device is diagnosed to be partly available.

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